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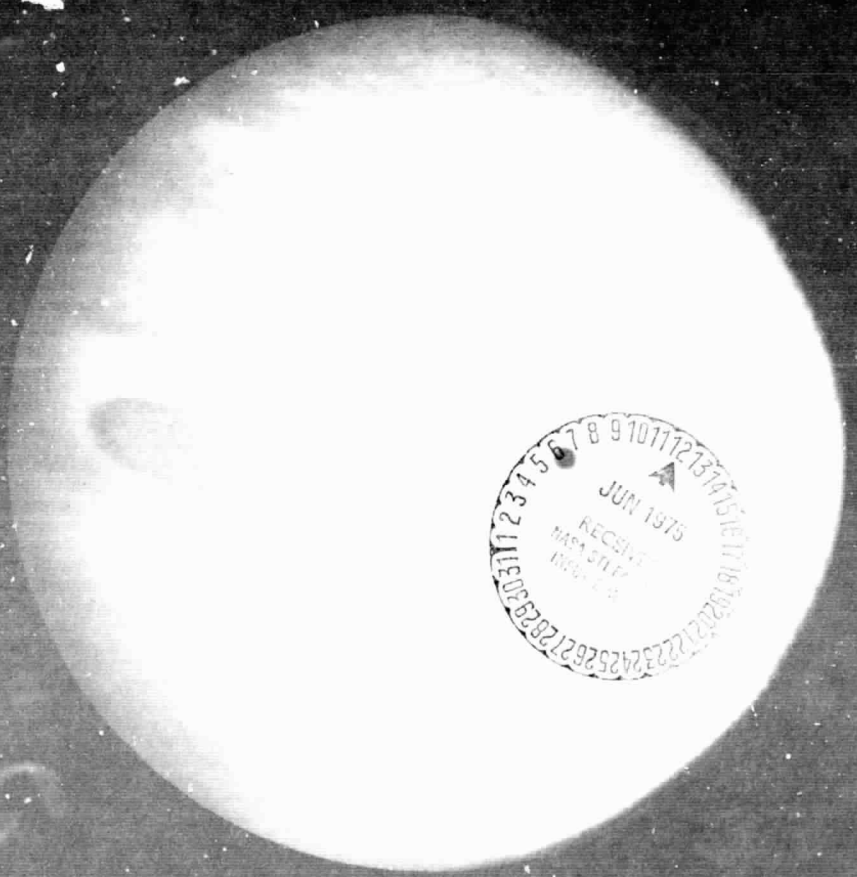
MAN LINKS EARTH AND PLANETS

PIONEER TO JUPITER



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ENCOUNTER WITH JUPITER

PIONEER TO JUPITER, ENCOUNTER WITH JUPITER

At precisely 6.26 p.m. PST on December 3, 1973, Pioneer 10 will hurtle past Jupiter only 81,000 miles above the cloud tops (Figure One). During the two weeks around that date a team of spacecraft controllers, analysts, and scientists at NASA's Ames Research Center, and personnel of NASA's Deep Space Network, will run a three-shift, 24-hours-a-day control operation. Constantly alert to danger to the spacecraft from possible but unpredictable problems due to unknowns in the environment of Jupiter, these men will send up to 15,000 commands to the distant spacecraft during this period.

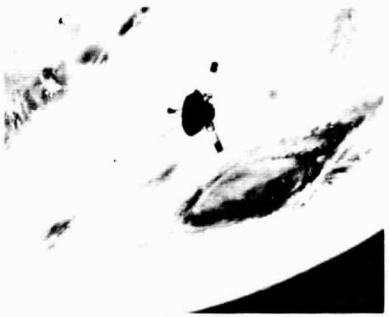

Figure 1. Pioneer flying over the Great Red Spot.

They have been rehearsing their roles for months now, getting prepared to tackle every conceivable problem that might arise to endanger this first mission to Jupiter, giant of the Solar System.

Their job is complicated by the 92 minutes needed for signals to reach Jupiter. To save weight and keep the cost of the spacecraft low, the Pioneers are controlled by people sending commands from Earth rather than making the spacecraft completely automatic. But controllers have to wait an hour-and-a-half from sending a command to knowing the spacecraft has done what they want it to do. That's the time that radio waves, traveling at 186,000 miles per second, take to travel to the spacecraft and back.

Well in advance of Jupiter encounter, the men at Pioneer control turn on most of the spacecraft's subsystems and scientific instruments. They leave them operating throughout the encounter. If all goes well only a few routine spacecraft operations will then need to be commanded, such as checking that the pointing direction is correct so that signals are directed accurately toward Earth, or changing, as needed, the precise order in which information is returned to Earth. Only 5 of the 11 scientific instruments require commands. Most commands are to direct the sequence of pictures of Jupiter and its satellites.

In the months before encounter controllers test all the backup systems of the spacecraft so that spares carried aboard can be switched on to take over if some equipment fails as the spacecraft encounters the Jovian environment. For example, the radiation belts might seriously damage equipment and scientific instruments, and charged particles might stick to the spacecraft, especially when it is in Jupiter's shadow, and arcing could produce false commands to it.

Also, the mighty gravity of Jupiter could pull the spacecraft askew on its spin axis. And the spinning of the spacecraft could itself produce problems, turning the spacecraft into an electrical generator as it spins in Jupiter's magnetic field.

Finally, Jupiter could possess dust belts in a ring around the equator. While this dust would be invisible from Earth, impact with it could damage the spacecraft as it moves through the plane of Jupiter's equator just after closest approach to the planet.

So the men of Pioneer control have to be on their toes every second of the encounter period, ready to issue correcting commands to right any problems that might arise.

News from the spacecraft arrives back at Earth on three large antennas—210-foot dishes as large as football fields. One is in the Mojave Desert at Goldstone, California. Another is at Madrid, Spain, while the third is near Canberra, Australia. As the Earth turns on its axis, and the spacecraft with Jupiter sets at one of these Earth stations, the spacecraft rises at the next station. So signals can be received 24 hours each day.

And these giant antennas—the last two were completed and put into operation while Pioneer was on its way to Jupiter—can track the spacecraft to the enormous distance of more than 1.5 billion miles. Then the signals will take 4 hours to reach Earth.

THE ENCOUNTER SEQUENCE

Because Jupiter's gravity bends the spacecraft's course, the actual fly-by is a wide loop around the planet. Pioneer 10 approaches from Jupiter's sunlit side, then swings almost completely around its dark side. Planet rotation aside, Pioneer 10 flies two-thirds of the way around Jupiter at various distances. During the 48 hours of closest approach of Pioneer, Jupiter completes five rotations on its axis.

Pioneer 10 approaches in a counterclockwise direction—the same direction as Jupiter rotates—as seen from above the planet's north pole. Its path on the planet's surface passes over part of Jupiter's southern hemisphere, crosses the equator at an angle of 14 degrees, and leaves the planet over the northern hemisphere.

There are five stages in the two-month Pioneer encounter period from November 4, 1973 through January 3, 1974. (See Table One.) Stage One is the three weeks, November 4 through 24, during which the spacecraft passes from interplanetary space into the outer regions of the Jovian system, moving from about 15 million to 6 million miles from the planet.

Stage Two covers entry into the inner system. Sometime between November 25 and 29, Pioneer is expected to pass through the bow shock wave in the solar wind created by Jupiter's magnetic field and thus enter this magnetic field, the magnetosphere, of Jupiter.

Stage Three is that period when Pioneer continues flying through the outer magneto-

TABLE 1. DISTANCES DURING ENCOUNTER

DATE		TIME	DISTANCE FROM JUPITER, MILES	STAGE OF ENCOUNTER
NOV.	8	2.26 A.M.	14,680,000	
	11	10.26 A.M.	12,821,000	1
	22	6.26 A.M.	7,084,000	
	25	6.26 P.M.	5,180,000	
	27	6.26 P.M.	4,077,000	2
	28	6.26 P.M.	3,508,000	
	29	6.26 P.M.	2,923,000	
	30	6.26 P.M.	2,313,000	
DEC.	1	6.26 P.M.	1,666,000	3
	2	6.26 P.M.	943,800	
	3	6.26 P.M.	81,000	4
	4	6.26 P.M.	948,256	
	5	6.26 P.M.	1,660,000	
	6	6.26 P.M.	2,313,000	
	7	6.26 P.M.	2,922,000	
	8	6.26 P.M.	3,508,000	5
	9	6.26 P.M.	4,076,000	
	10	6.26 P.M.	4,633,000	
	11	6.26 P.M.	5,180,000	

sphere from about 3 to 2 million miles from the planet during November 30 through December 2.

Stage Four is the period of closest approach. It covers the last day and a half (38 hours) before closest approach of 81,000 miles on December 3. Here is where the spacecraft makes its most important measurements and flies by the big inner satellites. It takes hundreds of pictures and flies through the radiation belts.

Stage Five takes place as Pioneer flies away from Jupiter and repeats many of the earlier sequences in reverse order.

On November 8, during Stage One of the encounter, Pioneer 10 crosses the orbit of Hades, outermost satellite of Jupiter (Table Two). In the next few days it successively crosses the orbits of Pan and Andrastea. By November 11 Pioneer crosses the orbit of Demeter at 7 million miles from Jupiter, then Hera and Hestia. But the Jovian system is so big that despite the high speed of Pioneer it is not until December 3, the day of closest approach, that Pioneer crosses the orbits of the inner satellites. It comes within 865,200 miles of Callisto, which is as large as the planet Mercury. Next is close approach to Ganymede (larger than Mercury) of 277,300 miles, then to within 199,470 miles of Europa (size of Earth's Moon), and 221,840 miles of Io (larger than Moon). Pioneer approaches to 11,470 miles of the orbit of the innermost satellite Amalthea, but does not cross it.

First evidence at the spacecraft of Jupiter's presence may come on November 25 as Stage Two of the encounter begins. This is the earliest date for passage through the bow shock wave created as the solar wind hits the planet's magnetic field (see Table Three). The earliest date for entering Jupiter's magnetic field is November 29. Studies of this field can tell us about Jupiter's interior and more about the intense radio signals from the planet.

The first ultraviolet inspection of Jupiter starts on November 30 and continues for 38 hours, examining Jupiter's upper atmosphere to determine proportions of hydrogen and helium there. Also the instrument will look for polar glows or auroras (See Table Four).

A second viewing period, beginning 9 hours before closest approach, lasts for five hours. But the early view may be most important because closeness to Jupiter may blind the instrument with too much radiation.

Infrared inspection begins 18 hours before closest approach to measure temperatures of first Callisto, then Ganymede, Europa, Io, and Amalthea. Starting 2 hours and 11 minutes before closest approach, the instrument takes temperature measurements of Jupiter itself, its prominent features including the Great Red Spot, and its dark hemisphere.

Starting on November 5 an instrument known as IPP (short for imaging photopolarimeter) inspects light reflected from Jupiter to determine the nature of the atmosphere above the clouds as well as the structure and composition of the cloud layers. This instrument also inspects the satellites. And it acts like a television camera to provide information that is used to make pictures of the planet and its satellites.

At around six hours before closest approach, Pioneer 10 enters the zone of hard radiation known as the radiation belts and starts charting this region to precisely define its hazards to spacecraft flying close by the giant planet.

Three hours before closest approach, the Great Red Spot is probed by a variety of scientific instruments to gain a better understanding of this mysterious region.

Closest approach is called periapsis. It takes place at 6.26 p.m. PST, on December 3 when Pioneer literally skims across the cloud tops at 82,000 miles an hour; perhaps even faster. Ten minutes afterward Pioneer passes through the equatorial plane and will encounter any dust belt that may be present there. An increase in dust concentration of up to 1000 times that in the interplanetary environment might occur, but hopefully not enough to damage the spacecraft.

TABLE 2. TIMES OF CROSSING SATELLITE ORBITS

SATELLITE	DATE	TIME	DISTANCE FROM JUPITER, MILES
HADES	NOV. 8	2.26 A.M.	14,680,000
POSEIDON	8	10.26 A.M.	14,420,000
PAN	9	12.26 A.M.	13,840,000
ANDRASTEA	11	10.26 A.M.	12,821,000
DEMETER	22	2.26 P.M.	7,231,000
HERA	22	2.26 A.M.	7,243,000
HESTIA	22	6.26 A.M.	7,085,000
CALLISTO	DEC. 2	12.26 P.M.	1,125,000
GANYMEDE	3	4.26 A.M.	496,400
EUROPA	3	10.26 A.M.	372,500
IO	3	2.26 P.M.	221,300
AMALTHEA	3	6.26 P.M.	*

*PIONEER DOES NOT GET CLOSE ENOUGH TO JUPITER TO CROSS THIS ORBIT.

TABLE 3. SOME IMPORTANT EVENTS

DATE	TIME	EVENT
NOV. 24	6.26 P.M.	ENTER THE BOW SHOCK WAVE (EARLIEST)
28	6.26 P.M.	ENTER JUPITER'S MAGNETIC FIELD (EARLIEST)
DEC. 3	11.26 P.M.	ENTER CRITICAL REGION OF INTENSE RADIATION (RADIATION BELT)
	6.36 P.M.	CROSS EQUATORIAL ZONE WITH POSSIBLE DUST HAZARD
	6.41 P.M.	GO BEHIND IO (OCCULTATION)
	7.42 P.M.	GO BEHIND JUPITER (OCCULTATION)
	8.16 P.M.	ENTER INTO JUPITER'S SHADOW
4	12.26 A.M.	LEAVE HARD RADIATION BEHIND
19	—	LEAVE THE BOW SHOCK
JAN. 2	—	END OF ENCOUNTER SEQUENCE

TABLE 4. SOME EXPERIMENTS

DATE	TIME	EVENT
NOV. 30	2.26 P.M.	FIRST ULTRAVIOLET LOOK AT JUPITER
DEC. 2	7.05 A.M.	INFRARED LOOK AT CALLISTO
3	3.17 A.M.	INFRARED LOOK AT GANYMEDE
	8.40 A.M.	SECOND ULTRAVIOLET LOOK AT JUPITER
	11.08 A.M.	INFRARED LOOK AT EUROPA
	12.38 P.M.	INFRARED LOOK AT IO
	3.45 P.M.	LOOK AT THE GREAT RED SPOT
	4.18 P.M.	INFRARED INSPECTION OF JUPITER
	6.14 P.M.	INFRARED LOOK AT AMALTHEA

At 15 minutes after closest approach, the spacecraft passes behind Io. As it does so refraction effects bend and weaken the radio signals from the spacecraft and enable scientists to calculate what sort of an atmosphere Io possesses. It could be that an electrically charged atmosphere links up lines of force in Jupiter's magnetic field and causes enormous electrical discharges in Jupiter's atmosphere to generate powerful radio signals received on Earth from the planet. Pioneer should be able to check if this is true.

An hour after passage behind Io, the spacecraft goes behind Jupiter itself for 65 minutes. Similar bending and weakening of free electrons in Jupiter's ionosphere (electrified upper atmosphere) and something of the density and composition of Jupiter's atmosphere in general. These measurements are made as the spacecraft both goes behind and emerges from the bulk of Jupiter.

At 2 hours and 51 minutes after closest approach, Pioneer enters the awesome shadow of the huge planet and remains in darkness for 51 minutes. On returning into sunlight Pioneer starts to leave the environment of Jupiter and as it heads for the stars of the Galaxy it makes as many similar measurements of the Jovian system as when it came in. In the weeks following encounter the spacecraft continues to make measurements of the solar wind and of particles and magnetic fields in space. It will try to find out what effects Jupiter has on the interplanetary environment outside the big planet's orbit. There are several unanswered questions about space beyond Jupiter's orbit that Pioneer may throw light on. How many and what types of cosmic rays come into the Solar System from the Galaxy? What is the distribution of hydrogen and helium in space beyond Jupiter and where does it originate? Where is the boundary at which the solar wind stops blowing and interstellar space—the space between the stars—really begins?

Communications may be maintained with Pioneer for five years, though the mission was designed for only several months encounter. As the communications distance becomes steadily longer, the incoming signals will become incredibly faint. But the link with Pioneer may last until it crosses the orbit of Uranus in 1979, then to be lost as the tiny emissary of mankind carries its message of an intelligent race on Earth into the cosmos.

THE PICTURES OF JUPITER AND ITS SATELLITES

Pictures of Jupiter could be disappointing. Scientists do not know how the equipment will stand up to the hostile environment of the mighty planet. But if all goes well the pictures may provide inspiring views of the big planet and its planet-sized moons.

Building up pictures of Jupiter and the satellites begins on November 5. Early images are used to test the equipment—then, on November 26, the image-making sequence goes to a 23 hours-a-day basis. Forty-eight hours before closest approach, the pictures from Pioneer are expected to be better than any obtained from Earth with the largest telescopes. And by eight hours before encounter, the image of Jupiter fills the field of view of the picture making system.

There are plans for more than 300 views of Jupiter and ten of its satellites in the two weeks period, including some close-ups of satellites (see Table Five). As Pioneer flies around the night side of Jupiter, view angles impossible from Earth are obtained. If the imaging system withstands the passage through the radiation belts spectacular pictures of the close approach may reveal features 100 miles across, of cloud currents and eddies, and provide new information on features such as the Great Red Spot. These pictures will be made available to national television as soon as they have been processed by the computers at NASA's Ames Research Center.

WHAT TO LOOK OUT FOR

Television, radio and newspapers will start carrying reports on Pioneer's progress about a month before closest approach. As pictures and results flood back from the Jovian system, television will give the news quickly. A day later newspapers will carry more detailed reports. But for the complete story we have to wait for weeks or months until scientists can analyze the wealth of new information and write interpretive articles for magazines such as Scientific American and Science News. A few newspapers will also carry these detailed science stories, too.

PIONEER 11

From the results of Pioneer 10's flight past Jupiter, project engineers and scientists will decide how Pioneer 11 should be directed for its encounter in December, 1974. If Pioneer 10 is damaged by the environment of Jupiter, particularly the radiation and possible dust belts, Pioneer 11 may be directed to fly by further out from the planet. But if Pioneer 10 emerges unscathed, Pioneer 11 might be sent even closer to further test the radiation belts.

STUDY PROJECTS

ONE

Take the various events listed in Tables 1 through 5 and make a combined listing of the sequential happenings when Pioneer 10 flies through the Jovian system. List the date, time, what happens, and leave a column for remarks about each event.

TWO

Use the list you have made during the encounter. Watch TV, listen to radio, and read the newspapers to check each event as it is reported. Fill in remarks as to what is discovered. Use this information to check your study projects made in connection with earlier leaflets of this series. Check your drawing or painting of Jupiter (leaflet #2) to see if you guessed right what the planet looks like. Also check and correct your 'unknowns' list of leaflet #3.

READING LIST

Watch TV newscasts and special programs.

Listen to radio newscasts.

Read your local newspaper or national newsmagazines.

TABLE 5. PHOTOGRAPHS (IMAGES) OF JOVIAN OBJECTS

DATE	APPROXIMATE NUMBER OF PICTURES	OBJECT
NOV. 26	12	JUPITER
27	26	JUPITER
29	25	JUPITER
30	20	JUPITER
DEC. 1	26	JUPITER
	2	IO
2	23	JUPITER
	2	IO
	2	CALLISTO
	2	GANYMEDE
3	18	JUPITER
	1	IO
	1	EUROPA
4	23	CRESCENT-SHAPED JUPITER
5	22	JUPITER
6	16	JUPITER
7	31	JUPITER
8	25	JUPITER
9	38	JUPITER
10	20	JUPITER

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